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PROPOSITION DE SUJET DE THESE / PHD THESIS PROPOSAL

Intitulé/Title : Numerical modelling and investigation of approaches to mitigate Transverse Mode Instabilities in high power fiber lasers

Référence : **PHY-DOTA-2024-32**
(à rappeler dans toute correspondance)

Début de la thèse : according to specific agreement for international PhD thesis (Univ. Paris-Saclay, EDOM)	**Date limite de candidature/ Candidate :**

Mots clés / Keywords:

Fiber lasers - fiber amplifiers – power scaling - nonlinear effects mitigation – Stimulated Brillouin Scattering – Transverse Mode Instabilities

Profil et compétences recherchées / Main skills required for the PhD thesis:

Lasers – optics – fiber optics – numerical modelling – laser, optics and fiber optics experiments

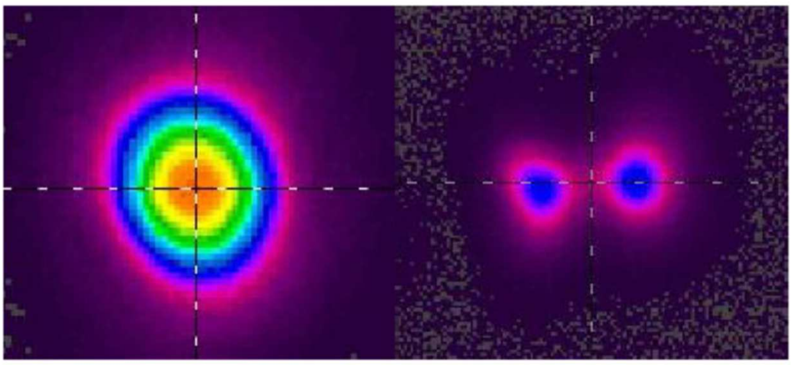
Présentation du projet doctoral, contexte et objectif:

Laser weapon systems developments present extreme challenges in terms of output power required from continuous wave fiber lasers and amplifiers. Moreover, the use of laser combining techniques is required to achieve the levels of power needed for this challenging application, in order to efficiently add the powers from a large number of these high-power fiber sources. These combining techniques induce additional challenges such as the narrowing of the laser linewidth.

One of the main power limitations for “combinable” narrow-linewidth fiber lasers and amplifiers is due to nonlinear (NL) effects triggered by the very high intensities reached in the narrow diameter cores of the fibers: Stimulated Brillouin Scattering (SBS) is the first NL effect encountered, as soon as at 30-W level of power in a large core diameter Yb-doped fiber, then followed by another NL effect, Transverse Mode Instabilities (TMI), that generally appears between 100 and 200 W in such fibers.

Onera has developed numerical models of fiber amplification capable of predicting the SBS threshold accurately, as well as different SBS mitigation techniques. They have been applied to develop high peak power pulsed fiber amplifiers at 1.5 µm for Doppler Lidar applications as well as continuous-wave fiber amplifiers at 1 µm for laser weapon applications.

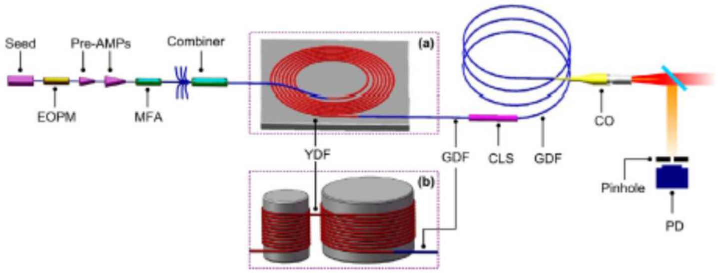
However, these numerical models are not yet capable of predicting the Transverse Mode Instabilities NL effect threshold. One of the first objectives of this PhD thesis will be to develop, from the abundant literature on the subject, the nonlinear numerical models of TMI to complement the library of models of fiber amplification and SBS threshold prediction already available at Onera.



Pair of transverse modes (LP_{01} + LP_{11}) amplified in a fiber suffering from TMI limitations.

These numerical models will then be compared with experimental tests for validation, either pulsed or continuous-wave lasers or amplifiers experiments. Multiple setups are available or can be assembled at Onera for these tests, at either one of the 3 wavelengths of choice for fiber lasers: 1 µm, 1.5 µm (pulsed only) or 2 µm. Studying the impact of the wavelength and comparing these 3 wavelengths in terms of TMI threshold is an important part of the thesis, as TMI thresholds for 1.5-µm and 2-µm fiber lasers are much less studied than for 1-µm lasers, and it seems, but has yet to be confirmed numerically and experimentally, that this threshold does increase with the wavelength of the laser.

In the literature, there are different approaches that have been tested to mitigate the TMI effects and increase TMI threshold. The third step of the thesis will be to investigate some of these approaches both numerically and experimentally, to compare their performances and to understand their limitations.



Example of approach allowing to mitigate TMI effects by proper coiling of the fibers.

Finally, as TMI is a NL effect that appears in narrow-linewidth fiber amplifiers once SBS has been mitigated, the PhD student will contribute to investigate some of the newest methods for SBS mitigation that have been implemented by the team. Other nonlinear effects that could result in detrimental limitations to fiber amplifiers power scaling will also be considered, in order to analyze the synergy, possible antagonisms, in one word “compatibility” between TMI and other nonlinear effects’ mitigation techniques.

Collaborations envisages:

Royal Military Academy, Brussels (Belgium) – International PhD thesis within the frame of a specific agreement proposed by University Paris-Saclay, EDOM (Ecole Doctorale Ondes et Matière)

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